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DISTRIBUTION SYSTEM SURVEY

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DISTRIBUTION SYSTEM SURVEY

Report prepared by:

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Water Resources Branch
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Executive Summary

In 1981, 1983, 1985 and 1986, the Ministry of the Environment (MOE) conducted surveys of drinking water quality at selected communities in Ontario.

This report presents a compendium of data collected during the four year study. Individual reports for each municipality surveyed are on file at the MOE, Water Resources Branch, Drinking Water Section office.

The purpose of the Distribution System Surveys was to evaluate the quality of municipal drinking water, particularly the water at the consumer's tap. Raw, treated, and distributed water quality from supplies using ground water and surface water was monitored at 77 municipalities across the province.

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1.0 **INTRODUCTION**

The delivery of high quality drinking water to the consumer's tap depends not only on the initial treatment the water receives, but also on conditions within the distribution system. Water may reside within the distribution system mains and household service connections for significant periods of time, in some cases days. During this time, changes can occur that affect both the aesthetic and health related quality of the water.

This report incorporates data obtained from a series of Distribution System Surveys (DSS) conducted in 1981, 1983, 1985, and 1986, by the Ministry of the Environment (MOE). The DSS were initiated to evaluate the quality of both the treated and distributed drinking water at selected Ontario communities. Of the 77 municipalities sampled, 70% had populations less than 10,000; thus, the sites selected were representative of the smaller systems in Ontario.

The purpose of the DSS was to determine the general state of selected Ontario municipal drinking waters and distribution systems using a standard sampling protocol and analyses and to determine changes in water quality that may have occurred along the route from leaving the water treatment plant to the consumer's tap.

Raw water sources include ground water and surface water, rivers and lakes. At each of the 77 municipalities involved, samples of raw, treated, and distributed water were collected. In each case, the quality of drinking water in the distribution system is compared to that of the raw and treated water. The reasons for apparent changes in water quality that may have occurred during distribution are examined.

Analyses were performed for a wide variety of water quality parameters under the headings of Field Data, General Chemistry, Metals, Bacteriological Content, and Macro-Organisms. Testing for trace organics and pesticides was not included in the DSS for several reasons, two of which were: limits for these substances in drinking water were not universally available at the time of the surveys; and they were not examined in other surveys.

Due to the vast data base accumulated over the four years, interpretation of results for all parameters is very complicated; hence, only a few important parameters are evaluated. The evaluation is based on the following criteria:

1. a comparison of the raw, treated and distributed water quality with relation to the source water, i.e. ground water, surface water lakes, or surface water rivers. The Ontario Drinking Water Objectives (ODWOs)[1] are used as a reference point for drinking water quality;

2. the effect of corrosion parameters (field pH, alkalinity, and Langelier Index) on the distribution system; and,

3. the effect of field pH, total chlorine residual, and alkalinity, on micro- and macro-organisms.

2.0 SYSTEM INFORMATION

The DSS included a total of 77 separate systems, comprising 22 ground water sources, 22 surface river sources, and 37 surface lake sources. Although several locations use more than one source, all have one distribution system. A summary of the sampling locations, the source waters, the types of treatment, and the date of sampling are given in Tables I, II, and III.

Of the 22 ground water sources, 7 had no treatment of any type, one was fluoridated, and the rest received disinfection (chlorination) only. All 22 river sources and 37 lake sources were chlorinated and 9 were treated for alkalinity adjustment or corrosion control.

TABLE I GROUND WATER SUPPLIES

	TREATMENT			
LOCATION	SOURCE	YEAR	MONTH	TYPE
Aurora	G	1981	07	D
Beeton	G	1986	10	D
Burk's Falls	G	1983	03	N
Caledonia	G	1981	05	D
Callander	G	1983	03	D
Campbellville	G	1981	08	FL
Capreol	G	1985	12	D
Cookstown	G	1986	10	D
Dymond Township	G	1983	03	N
Elora	G	1981	06	D
Erin	G	1981	06	N
Mattawa	G	1983	02	N
Milton	G	1981	07	N
Mount Forest	G	1981	06	N
New Liskeard	G	1983	03	D
Newmarket	G	1986	12	D
Plattsville	G	1986	09	D
Powassan	G	1983	03	N
Sault Ste Marie	G/SL	1986	11	D
South River	G	1983	02	D
Strathroy	G	1986	10	D
Trenton	G/SL	1981	07	D

SOURCE:
G = Ground Water SL = Surface Lake

TREATMENT TYPE:
N = None D = Disinfection FL = Fluoridation

TABLE II SURFACE RIVER WATER SUPPLIES

	TREATMENT			
LOCATION	SOURCE	YEAR	MONTH	TYPE
Brantford	SR	1981	07	D,FI,FL
Campbellford	SR	1981	06	D,FI
Cayuga	SR	1981	05	D,FI
Chapleau	SR	1981	07	D,AA
Delhi	SR	1981	06	D,FL
Gananoque	SR	1986	01	D
Hastings	SR	1981	06	D
Hearst	SR	1985	11	D,FI,CC
Latchford	SR	1983	02	D,FI,AA
Lindsay	SR	1981	06	D,FI
Marmora	SR	1981	07	D
Ottawa	SR	1986	01	D,FI,FL,AA
Pembroke	SR	1986	01	D,FI,AA
Peterborough	SR	1981	06	D,FI,FL
Rainy River	SR	1986	11	D,FI,AA
Sturgeon Falls	SR	1983	02	D,FI
Sudbury	SR/SL	1985	12	D,FL,AA
Thorne	SR	1983	03	D
Timmins	SR	1985	11	D,FI,CC
Trenton	SR/SL/G	1981	07	D,FI
Verner	SR	1983	02	D,FI,AA
Windsor	SR	1985	12	D,FI,FL

SOURCE:
SR = Surface River SL = Surface Lake
G = Ground

TREATMENT TYPE:
D = Disinfection AA = Alkalinity Adjustment
FL = Fluoridation CC = Corrosion Control
FI = Filtration

TABLE III SURFACE LAKE WATER SUPPLIES

			TREATMENT	
LOCATION	SOURCE	YEAR	MONTH	TYPE
Bancroft	SL	1981	07	D
Barry's Bay	SL	1986	01	D,FI,AA
Belleville	SL	1981	07	D,FI,FL
Bracebridge	SL	1981	06	D
Cache Bay	SL	1983	02	D
Cobalt SL	1983	03	D	
Deseronto	SL	1986	10	D,FI,AA
Dryden SL	1986	12	D,FI,FL,CC	
Dunnville	SL	1981	05	D,FI
Elliot Lake	SL	1985	12	D,FI,FL ,AA
Essex SL	1981	07	D,FI	
Fenelon Falls	SL	1981	06	D,FI
Goderich	SL	1985	12	D,FI,FL
Gravenhurst	SL	1981	06	D,AA
Haileybury	SL	1983	03	D,FI
Hamilton	SL	1981	06	D,FI,FL
Huntsville	SL	1981	06	D,FI,AA
Kenora SL	1985	11	D,FI,FL,AA	
Kingsville	SL	1981	07	D,FI
Kirkland Lake	SL	1985	11	D,FL
Leamington	SL	1981	07	D,FI
Nanticoke	SL	1981	06	D,FI
Nobel SL	1983	03	D	
North Bay	SL	1983	03	D,FL
Owen Sound	SL	1985	12	D,FI,FL
Parry Sound	SL	1983	03	D,FL
Picton SL	1986	10	D,FI,FL	
Sault Ste. Marie	SL/G	1986	11	D,FI
Sioux Lookout	SL	1985	11	D,FL
St. Thomas	SL	1986	10	D,FI,FL
Sudbury SL/SR	1985	12	D,FL,AA	
Temagami North	SL	1983	02	D,FI
Temagami South	SL	1983	02	D
Thunder Bay North	SL	1985	10	D,FI
Thunder Bay South	SL	1985	10	D,AA
Trenton SL/SR/G	1981	07	D,FI	
Wiarton SL	1986	11	D	

SOURCE:
SL = Surface Lake SR = Surface River G = Ground

TREATMENT TYPE:
D = Disinfection AA = Alkalinity Adjustment
FL = Fluoridation CC = Corrosion Control
FI = Filtration

3.0 SAMPLING PROCEDURES

Sampling was performed in accordance with the procedures outlined in the MOE publication, 'A Guide to the Collection and Submission of Samples for Laboratory Analysis'[2].

Although the fundamental objectives were not altered significantly during the course of the four year study, the methods employed therein were modified somewhat from year to year. Various sampling techniques were used depending on the type of analysis. At the water treatment plant, a sample of raw water was taken before it was subjected to any kind of treatment. The treated water, also at the plant, was sampled prior to distribution.

To obtain a profile of water quality in the distribution system, particularly with respect to inorganic and biological parameters, four different types of samples were taken (flushed, random, overnight and filtered).

1. Flushed Sample

A flushed sample was collected after water at the tap or hydrant was allowed to flow to waste for five minutes. This ensured that water was representative of the distribution system and not influenced by household plumbing. Where fire hydrants were sampled, care was taken to keep the flow to about 4 L/s so that sediment was not lifted from the mains. General chemistry, metal, bacteriological, and biological analyses were performed on the flushed sample as well as some on-site (field) testing.

2. Random Sample

A random sample was collected at unspecified times during the day (when the water may be used for consumption) and without prior flushing. The temperature of the water was recorded at the time of sampling and the sample was submitted for metal analysis.

3. Overnight Sample

During the 1985 and 1986 studies, an overnight sample was collected by the home occupant. Water was not used during the night for any purpose and the sample was collected first thing in the morning without prior flushing. Water temperature was recorded at the time of sampling and the sample was submitted for metal analysis. The overnight sample was taken to examine the level of metals leached from the domestic plumbing and service connections in the water supply.

4. Filtered Sample

A filtered sample was taken for biological analyses. A quantity of up to 30 L of water was passed through an in-line filter 47 mm in diameter with 8 μm pores. For hydrant samples, the volume filtered was usually around 4000 L and the filter pore size was as large as 75 μm. Any macro-organisms trapped on the filter were washed into sample bottles containing sodium thiosulphate to remove the chlorine. The purpose of this sample was to identify and quantify any organisms and other visible particles present in the water supply.

Table IV lists sampling method and parameter groups.

TABLE IV

SAMPLE TYPES AND PARAMETER GROUPS

		DISTRIBUTION SYSTEM (DS)		
RAW WATER	TREATED WATER	DS FLUSHED	DS RANDOM	DS OVERNIGHT
Field data	Field data	Field data		
*Temperature	Temperature	Temperature	Temperature	Temperature
Chemistry	Chemistry	Chemistry		
Metals	Metals	Metals	Metals	Metals
Bacteriology	Bacteriology	Bacteriology		
		Biological **		

* Field data

** Filtered sample

Locations for distribution system sampling were usually chosen in consultation with Public Utilities personnel. These locations were selected to be representative of the system as a whole based on distance from the water treatment plant, age, type, and size of the mains, and the probable volume of flow through the mains. Where possible, a few sites were also examined for worst case conditions such as dead-end mains and houses with lead and/or copper service connections. On occasion, sampling was done in response to consumer complaints.

In 1981, water was sampled at five homes and one fire hydrant in each distribution system. After 1982, the fire hydrant sample was no longer collected and the average number of locations sampled was increased to seven. In 1985 and 1986, household samples were taken at kitchen faucets. In previous years, the household sampling locations were not identified.

4.0 **ANALYTICAL PROCEDURES**

During the 1981 and 1983 studies, all laboratory analyses were carried out by the MOE, Laboratory Services Branch according to procedures outlined in the MOE publication, 'Outlines of Analytical Methods'[3]. Table V lists the water quality parameters that were investigated for the study.

With respect to the 1985 and 1986 studies, the consulting firms M.M. Dillon Limited, Proctor and Redfern Limited, and Canviro Consultants were engaged by the Ministry to conduct the DSS. Laboratory analyses were performed in-house by these firms or by private laboratories. All analyses followed the procedures outlined in either the previously mentioned MOE publication or, as in the case of Proctor and Redfern Limited, in the American Public Health Association's 'Standard Methods for the Examination of Water and Wastewater'[4].

Laboratory analyses were performed on a priority basis, bacteriological samples were received by the laboratory within 24 hours of sampling and analyzed without delay; macro-organism counts commenced immediately after sample receipt; analysis for general chemistry parameters was given routine priority; and analysis for metals was performed last to ensure that the work for each parameter was performed at the same time for all locations. This procedure simplified set-up and improved quality control.

TABLE V

SELECTED WATER QUALITY PARAMETERS

FIELD DATA	GENERAL CHEMISTRY	METALS	BACTERIOLOGICAL CONTENT
Chlorine, Free	Alkalinity	Aluminum	Fecal Coliform
Chlorine, Combined	Calcium	Antimony	Fecal Streptococci
Dissolved Oxygen	Colour	Arsenic	Standard Plate Count
pH	Conductivity	Barium	Total Coliform
Temperature	Cyanide	Boron	Total Coliform Background
	Dissolved Organic Carbon	Cadmium	
	Fluoride	Chromium	
	Hardness	Cobalt	MACRO-ORGANISMS
	Magnesium	Copper	
	Nitrogen, Ammonia	Iron	Algae
	Nitrogen, Kjeldahl	Lead	Cladocera
	Nitrogen, Nitrate	Manganese	Copepoda
	Nitrogen, Nitrite	Mercury	Nematoda
	pH	Molybdenum	Protozoa
	Phosphorous	Nickel	Other Materials
	Residue, Total	Selenium	Other Organisms
	Silicon	Silver	
	Sodium	Zinc	
	Sulphate		
	Turbidity		
	ASTM Index		
	Langelier Index		

5.0 RESULTS AND DISCUSSION

The results are discussed in three parts:

1. comparison of sample types versus source water;
2. effect of corrosion parameters (field pH, alkalinity, and Langelier Index) on distribution system; and
3. effect of field pH, total chlorine residual, and alkalinity on micro- and macro-organisms.

5.1 Comparison of Sample Type in Relation to Water Source

In relation to the three different water sources, three approaches are taken to examine water quality. First, the raw and treated waters (at the water treatment plant) are compared in order to detect significant changes that may have occurred during the treatment process. Secondly, the flushed water samples taken at houses in the distribution system are compared with the treated water at the plant. Lastly, the flushed, random, and overnight distribution system samples are compared. The latter two comparisons are made to assess the effect on water quality due to deterioration in the distribution mains, service connections, and household plumbing.

A compilation of analytical results are presented in the tables in Appendix A.

5.1.1 Field Data

Field parameters include free chlorine, combined chlorine, pH, dissolved oxygen and temperature. Chlorine residuals, both free and combined, are higher in the treated waters than in the flushed waters indicating a decline in the chlorine residual within the distribution system.

The mean pH remains relatively constant in the raw, treated, and flushed samples indicating no apparent distribution system effect. Results show that 68% of the flushed house samples from all sources have a pH between 7 and 8, 13% have pH levels between 8 and 9 and 16% have pH levels between 6 and 7.

Mean dissolved oxygen values are higher in the treated water than in the raw water. In the distribution system, values are lower indicating oxygen consumption.

5.1.2 General Chemistry

Twenty-two parameters were surveyed for general chemistry. The effect of treatment on different source waters is analyzed with respect to eight parameters; colour, turbidity, hardness, calcium, conductivity, alkalinity, dissolved organic carbon (DOC) and nitrate.

For the majority of locations using river water, an increase in conductivity and calcium and a decrease in turbidity and colour levels after treatment is observed. Parameters that do not vary greatly after treatment are DOC, hardness, nitrate and alkalinity.

When comparing these same parameters for lake water, it is found that nitrate levels are slightly higher after treatment. Alkalinity, colour, turbidity and DOC levels are lower after treatment. Hardness, conductivity and to some extent calcium levels show no change due to treatment.

In ground water, the majority of the parameters do not change after treatment. Turbidity and DOC levels are lower after treatment. Hardness, alkalinity, colour, conductivity and calcium levels do not change. Nitrate levels are slightly higher in the distribution system.

5.1.3 Metals

For the most part, metal levels are elevated in the overnight samples and to a lesser extent in the random samples as compared to levels in the treated water. Levels in the flushed samples are unchanged from the treated water. The average levels of arsenic, selenium, antimony, cobalt, molybdenum, silver and mercury remain constant from the raw water to the distributed water regardless of source. Levels reported are generally near or at the method detection limit.

Boron levels decrease in the distribution system. Levels of barium, copper, cadmium, chromium, iron, lead, manganese, aluminum, nickel and zinc are elevated in the distribution system as compared to the treated water. Of these, only lead, zinc, iron and copper exhibit elevated levels in the distribution system regardless of source waters. Other factors such as source seem to affect the levels of the other six parameters in the distribution system i.e. barium levels increase in the distribution system with a surface water source yet decrease when the source is ground water.

Lead levels for all sample types regardless of source are elevated in the distribution system. As indicated in the tables (Tables 20 -33), maximum lead concentrations exceed the ODWO of 0.05 mg/L in random and overnight distribution system samples from all sources and in the treated water when ground water is used. The levels of lead found in these samples ranges from 0.06 mg/L to 0.82 mg/L. Flushed samples have lower lead levels than random and overnight samples. Elevated lead concentrations are attributed to leaching from the zinc galvanized pipes and also to leaching from lead service connections. Concentration distribution for flushed samples from all sources show that 80%

have a lead concentration of less than 0.003 mg/L. Twenty flushed samples have values greater than 0.013 mg/L.

The accompanying questionnaire requested that the type of service connection at the distribution system location be noted. Only 19 identified a lead service connection.

Elevated levels of zinc are common in random and overnight samples. This may be a result of zinc leaching from galvanized plumbing. The maximum zinc concentration appears in the overnight samples; 3.54 mg/L, 3.24 mg/L, and 1.17 mg/L for ground, surface lake, and surface river sources, respectively. Approximately 87% of the flushed water samples contain less than 0.025 mg/L zinc.

Iron levels from all three sources decline after treatment but are elevated in the distribution system. Levels are highest in overnight samples. Elevated concentrations of iron in the distribution system are probably due to leaching in the iron mains. Results show that 90% of the flushed samples have less than 0.25 mg/L iron.

Copper results from all sources show that the levels increase in the distribution system. In general, the random and overnight samples have greater copper levels than flushed samples. Results for the flushed samples show that 65% of the residences have copper levels less than 0.05 mg/L and only 4% have copper levels greater than 0.25 mg/L. The copper distribution in the random samples from all sources indicates that only 31% have levels less than 0.05 mg/L. Thirty-eight percent have levels greater than 0.25 mg/L. The aesthetic ODWO for copper is 1.0 mg/L. An explanation of the elevated copper levels in the distribution system is presented later in the text.

5.1.4 Bacteriological Content

Analysis for bacteriological content has been used traditionally to ensure that water is pathogen free and is monitored by municipalities on a routine basis. It was included in the DSS to complete the evaluation of the effect of distribution on water quality and monitor changes. Bacteriological analysis include: fecal coliform, total coliform, background, fecal streptococci, and standard plate count (SPC).

When raw and treated waters are compared, it is found that treatment, regardless of type, is effective in producing bacteriologically safe water. In reviewing the flushed water samples, bacteriological quality is maintained in the distribution system except for two locations: fire hydrants and houses on the dead end section of the system. The bacteriological quality at these locations is poor compared to just after treatment. A low chlorine residual is reported at these locations. As will be noted later, a general association between increased bacteria counts and decreased chlorine residual is found.

5.1.5 Macro-organisms

Macro-organisms are part of the normal fauna of water and may be present in water distribution systems. Although the macro-organisms are not themselves of health concern, they may harbour pathogenic organisms and affect the aesthetic quality of the water, especially if they are abundant. The macro-organisms studied in the DSS include nematoda, copepoda, cladocera, protozoa, and algae, as well as 'other' organisms and materials. Some algae, protozoa, and other organisms, which are common in either soil or surface waters, can cause taste and odour problems and deplete chlorine residuals. Although most of these organisms are removed by conventional treatment processes, several are able to pass through and others may gain access through improper construction, repair or maintenance procedures of the distribution system. The larger visible organisms can reproduce in the distribution system, remain in sediments, and create local aesthetic problems where water quality is allowed to deteriorate.

Irrespective of source, treatment is successful in decreasing the number of macro-organisms or maintaining them at a low level. Conventional treatment (i.e. treatment with more than just chlorination) is more effective than disinfection alone. Macro-organisms are more abundant in the flushed waters. This may be a result of low chlorine residual in the distribution system or disturbance from sediments.

5.2 Effects of Corrosion Parameters on the Distribution System

Correlation between specific metal concentrations in the distribution system and pH, alkalinity and Langelier Index are reviewed with respect to corrosion. Graphical correlations are presented for lead and copper results. The discussion compares all residences regardless of plumbing type. Included are residences with copper plumbing and residences with lead service connections.

5.2.1 All Residences

The number of flushed samples exceed the number of random or overnight samples since overnight standing samples were taken only in the 1985 and 1986 surveys.

Lead concentrations, as expected, are higher in the overnight and random samples as opposed to flushed water samples (Figure 1). Lead concentrations are also highest at pH between 7 and 8. Copper concentrations, as with lead, are higher in the overnight and random samples than the flushed samples (Figure 2). Concentrations are highest at pH between 6 and 7.

Results show that the majority of the samples could be grouped into two ranges for alkalinity; less than 100 mg/L $CaCO_3$ and between 150 and 250 mg/L $CaCO_3$. The mean alkalinity is 95 mg/L with a standard deviation of ± 79 mg/L $CaCO_3$ indicating the high variability in waters. Even though most of the samples are found in the lower alkalinity range where there is an undersaturation of calcium carbonate, only a few random and overnight samples exhibit elevated copper levels. A number of random and overnight samples are observed to have elevated lead levels (Figure 3 and Figure 4).

Although low alkalinity waters may accelerate the leaching process, the effect of alkalinity on metal leaching from the distribution system is minimal. It should be noted that other factors such as treatment (i.e. corrosion control and alkalinity adjustment) are not taken into account. These must be assessed for individual municipalities.

The Langelier Index (LI) is a measure of the ability of a water to deposit scale or to corrode. The calculation is based on the degree of saturation of the water with respect to $CaCO_3$. If the water is saturated, it will neither scale nor corrode. A water with a positive LI is termed oversaturated and will tend to deposit scale. A water with a negative LI will tend to be aggressive, dissolving any scale present. Results show elevated levels of metals occur when the LI is both positive and negative.

No association can, therefore, be made between leaching of metals and a negative LI. A mean LI of -0.80 ± 1.39 is found indicating that more than half of the locations tested have fairly aggressive waters.

5.2.2 Residences with Copper Plumbing

Residences with copper plumbing were sampled in order to determine the effect on metal levels. Appendix A, Table 44 shows that maximum copper values are highest in residences with copper plumbing.

5.2.3 Residences with Lead Service Connections

The number of residences with lead service connections is much lower than with copper plumbing. The effect of type of service connection on metal content is more apparent when compared to homes with copper service connections as shown in Figures 5 and 6. Flushed samples from residences with lead service connections have higher lead levels than flushed samples from residences without lead service connections. Also, the mean lead level in overnight samples is elevated when compared to all residences regardless of plumbing. Increased overnight leaching of lead, therefore, is more apparent in residences with lead service connections.

The effect of low alkalinity water on residences with lead service connections is most apparent in the overnight samples. The lower the alkalinity the higher the lead dissolution. This is also apparent in flushed samples (Figure 5). A positive but relatively weak correlation can be made between alkalinity and lead leaching from lead service connections.

5.3 Effects of pH, Chlorine, and Alkalinity on Biological Content

The effects of field pH, total chlorine residual, and alkalinity on bacterial and biological species are examined for total coliforms, background coliforms, standard plate counts and nematodes.

With respect to the corrosion parameters, it is found that neither pH nor alkalinity affect micro- or macro-organisms. That is, no correlation can be made between pH or alkalinity and bacterial and/or biological populations in the distribution system.

On the other hand, an inverse relationship exists between the total chlorine residual and the number of organisms present. As the total chlorine concentration decreases, the number of micro- and macro-organisms increases. Results indicate that a minimum total chlorine residual of 0.5 mg/L is needed to maintain a bacteriologically and biologically safe water throughout the distribution system. An average value of 1.0 mg/L total chlorine residual is optimum.

5.4 Summary

The vast amount of data for varying water sources makes trend analysis difficult. Results indicate that source specific trend analyses may be more realistic. The data set lacked uniformity. Parameters analyzed were not consistent, data on type of service connection or plumbing information was erratic and many distribution system sites selected received water from more than one source. Data from these locations could not be used.

In addition, other factors such as distance from treatment plant to consumer's tap, age of distribution system, materials used in the plumbing system, length of service connection, type of taps and fixtures, or sampling location in the home may have been significant in determining water quality at the tap.

6.0 CONCLUSIONS

The purpose of this survey was to acquire water quality information on the distribution system specifically at the consumer's tap and assess the effects of source water, treatment and distribution on water quality. Overall results generated a good 'picture' of water quality in distribution systems. Each water supply was monitored for quality of source water and after treatment water but monitoring for water quality in the distribution system was limited.

Specific parameters were altered by treatment, treatment and distribution and distribution alone. Field parameters, general chemistry, bacteriological parameters and macro-organisms were influenced by treatment. Bacteria and macro-organism analyses showed that treatment was effective in producing bacteriologically safe waters in the distribution system. Although still safe, levels were higher due to lower chlorine residual.

Levels of most metals increased in the distribution system. Flushed samples had the lowest levels of metals. Random and overnight samples had the highest levels of metals. Alkalinity and pH influenced metal levels. The highest metal levels were detected at either the low alkalinity range or at a pH of 6.5. This correlation, however, was not conclusive. A more definite relationship existed between the material used in the service connection and metal content. Lead levels in flushed samples exceeded 0.01 mg/L more often when a lead service connection was identified than with a copper service connection.

The underlying principle resulting from this study was that water has a tendency to corrode and dissolve.

7.0 **RECOMMENDATIONS**

The Distribution System Survey generated sufficient data to indicate that distribution system conditions influence water quality. Non-uniformity in sampling and incomplete data for sampling sites prevented evaluations for correlation and trend analysis. Further investigation on individual municipalities conducted in a uniform manner would supplement this data and enable more complete evaluations.

Figure 1

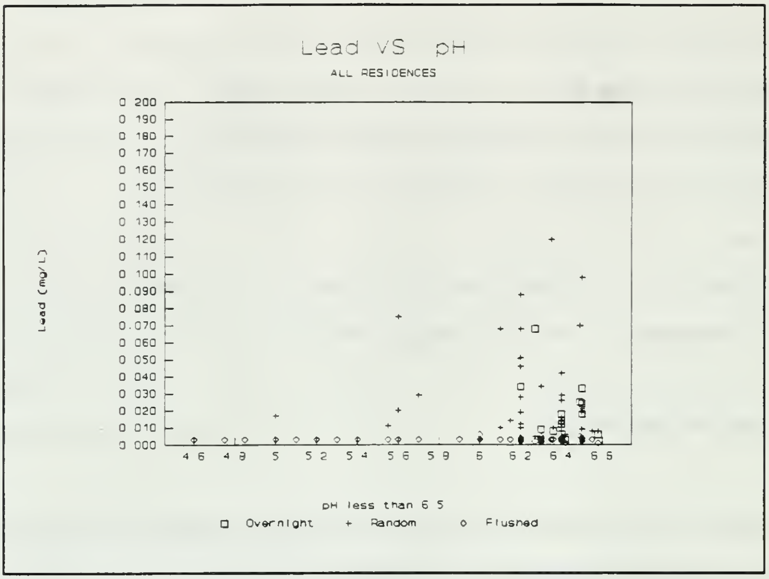


Figure 1.1

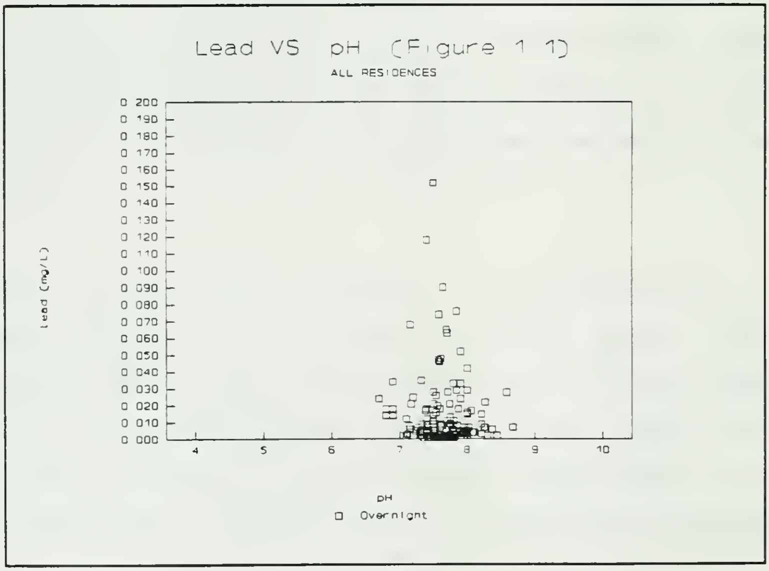


Figure 1.2

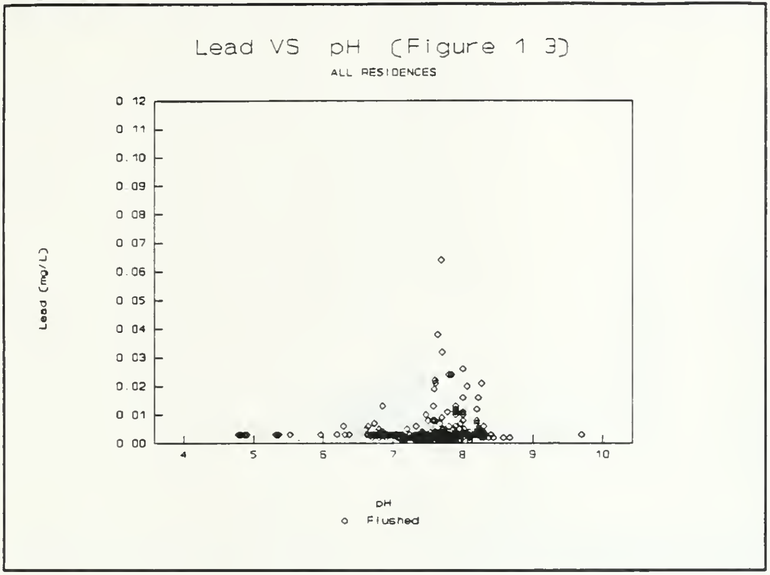


Figure 1.3

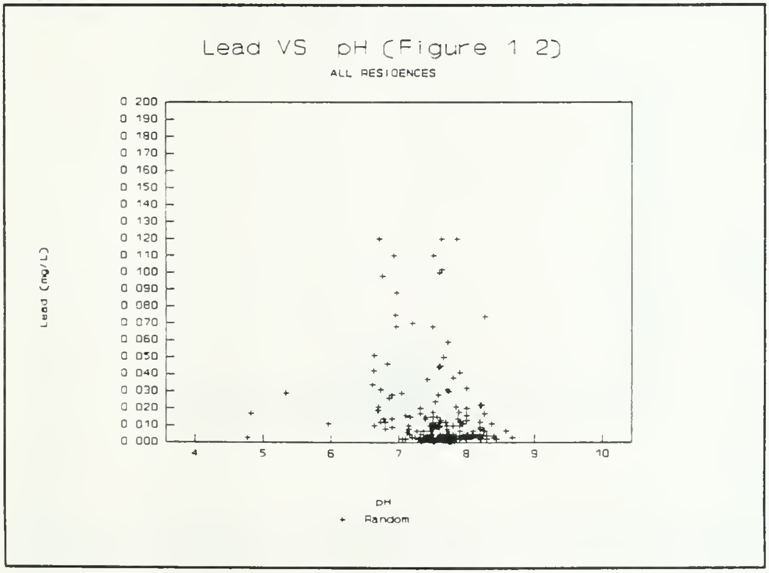


Figure 2

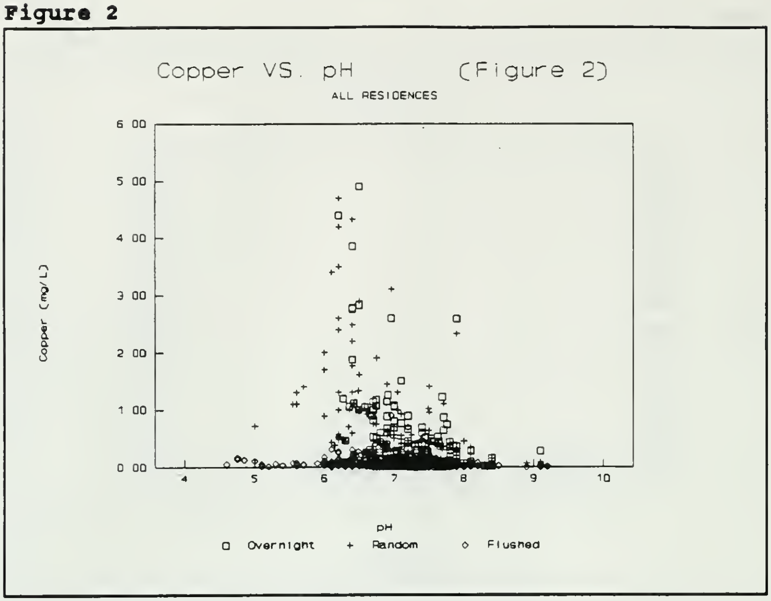


Figure 2.1

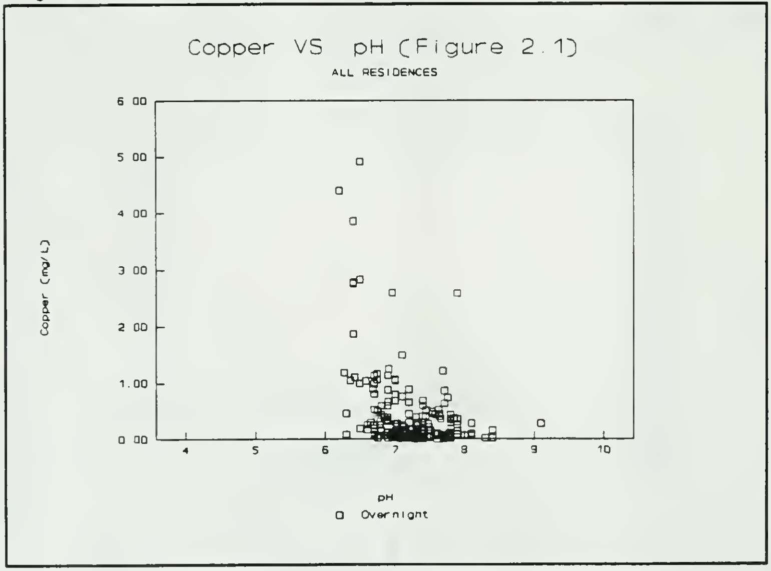
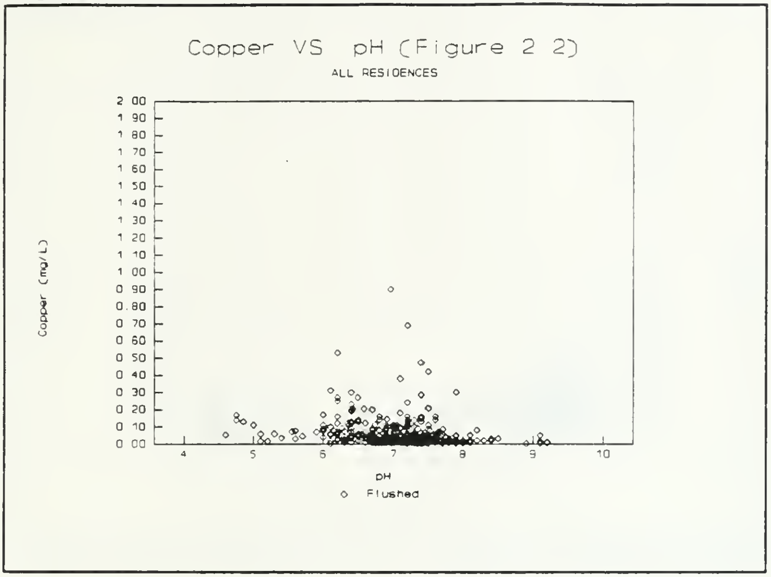


Figure 2.2



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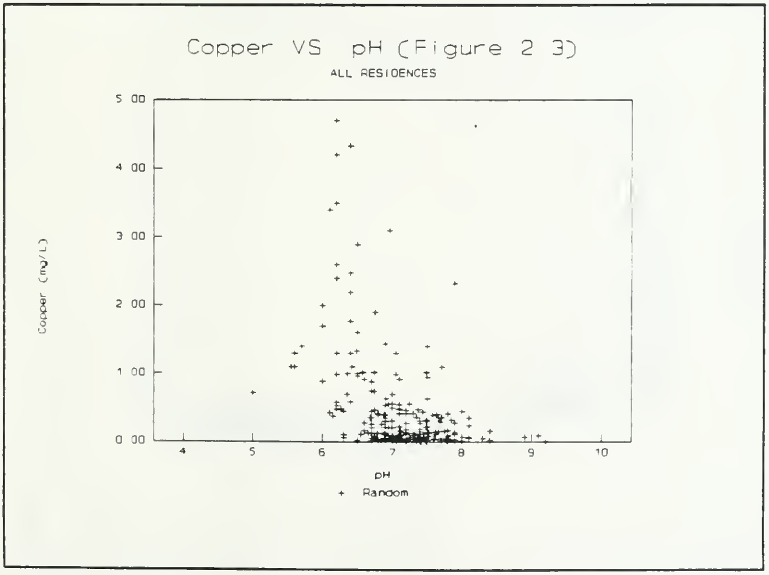
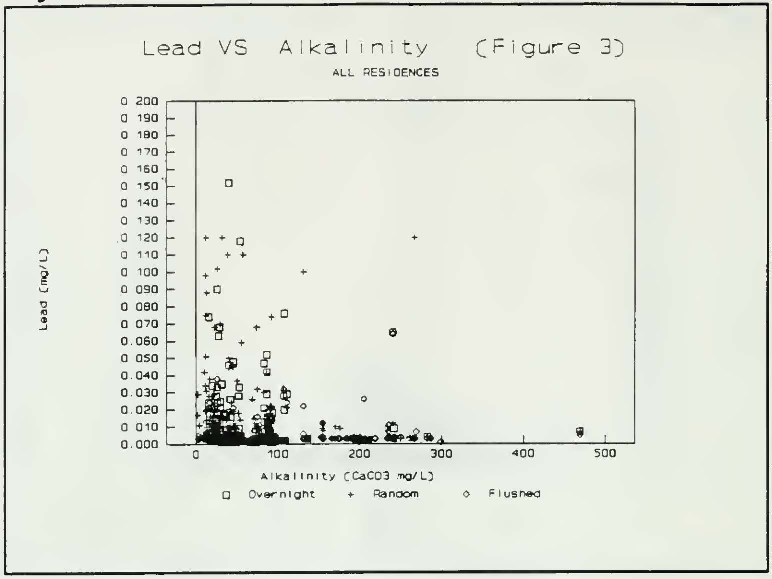


Figure 3



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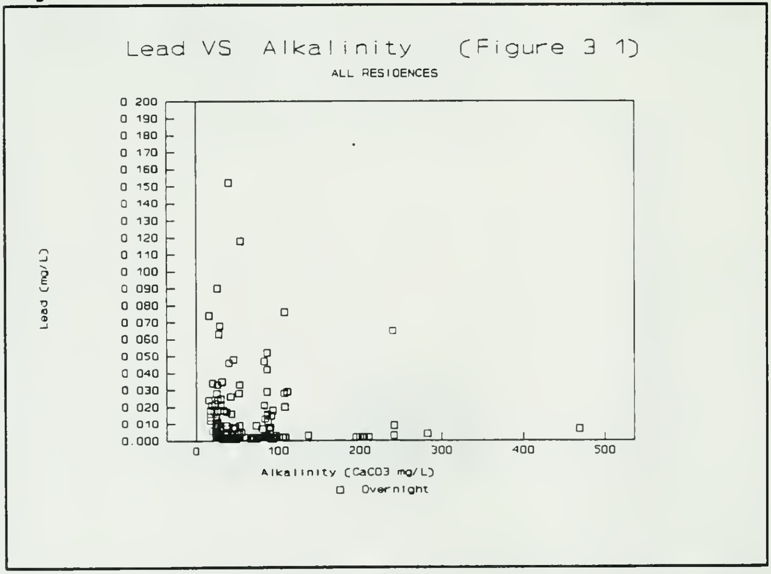
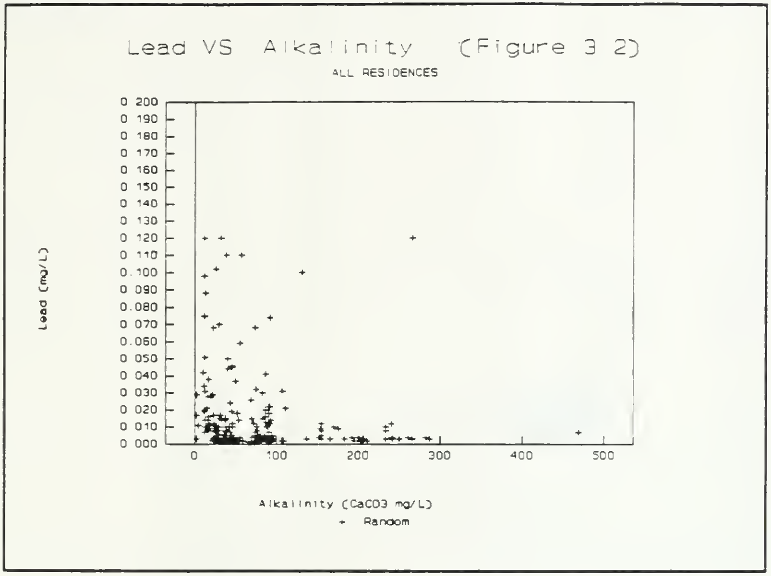


Figure 3.2



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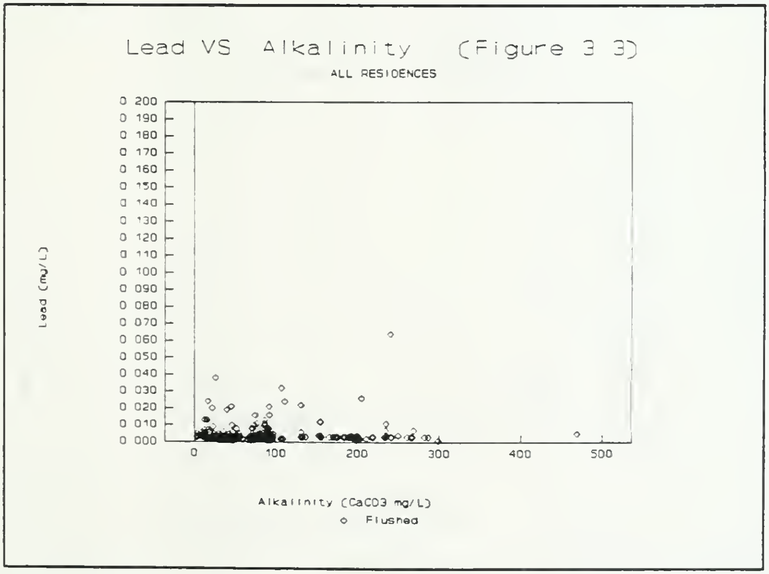


Figure 4

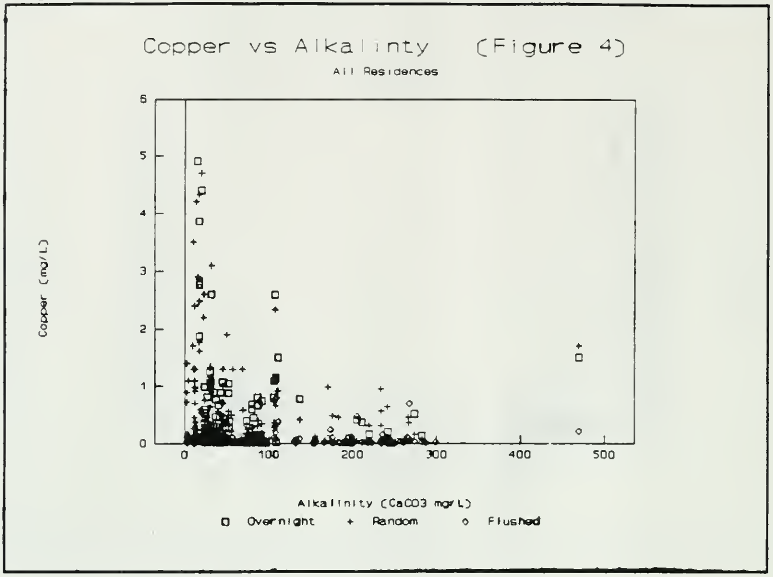


Figure 4.1

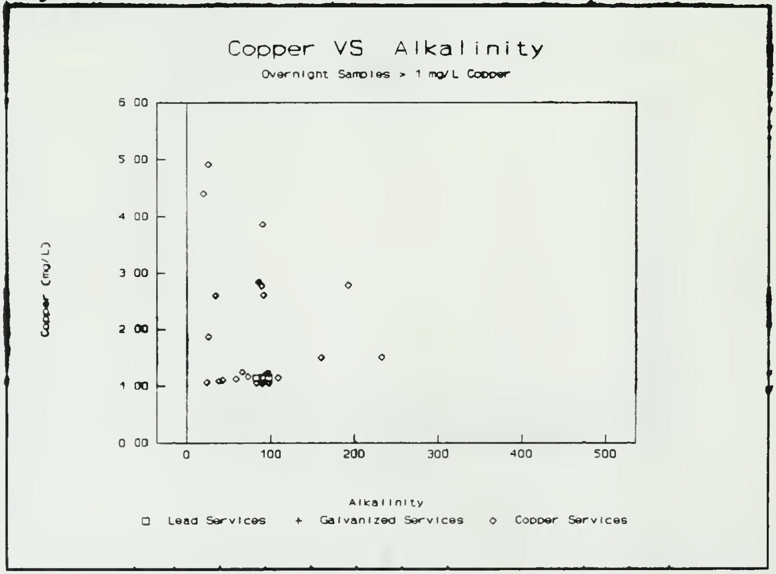


Figure 5

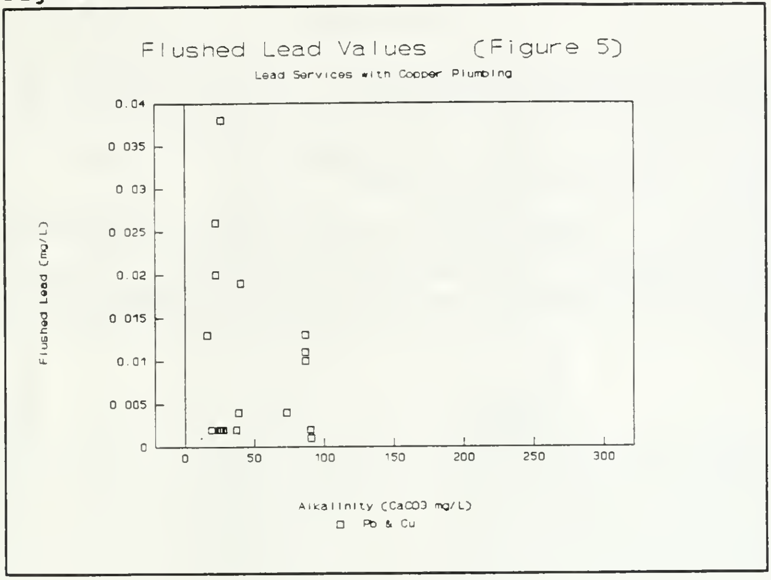
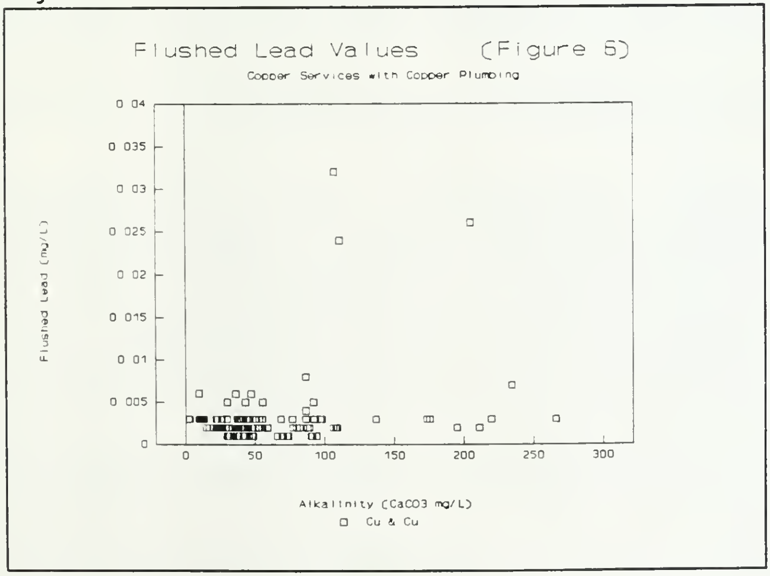


Figure 6



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APPENDIX A

LOCATIONS	SRCE	TMNT	SAMP DATE	LOCATIONS	SRCE	TMNT	SAMP DATE	LOCATIONS	SRCE	TMNT	SAMP DATE
AURORA	G	D	07 / 1981	BANCROFT	SL	D	07 / 1981	BRANTFORD	SR	D,FI,FL	07 / 1981
BEETON	G	D	10 / 1986	BARRY'S BAY	SL	D,FI,AA	01 / 1986	CAMPBELLFORD	SR	D,FI	06 / 1981
BURK'S FALLS	G	N	03 / 1983	BELLEVILLE	SL	D,FI,FL	07 / 1981	CAYUGA	SR	D,FI	05 / 1981
CALEDONIA	G	D	05 / 1981	BRACEBRIDGE	SL	D	06 / 1981	CHAPLEAU	SR	D,AA	07 / 1981
CALLANDER	G	D	03 / 1983	CACHE BAY	SL	D	02 / 1983	DELHI	SR	D,FL	06 / 1981
CAMPBELLVILLE	G	FL	08 / 1981	COBALT	SL	D	03 / 1983	GANANOQUE	SR	D	01 / 1986
CAPREOL	G	D	12 / 1985	DESERONTO	SL	D,FI,AA	10 / 1986	HASTINGS	SR	D	06 / 1981
COOKSTOWN	G	D	10 / 1986	DRYDEN	SL	D,FI,FL,CC	12 / 1986	HEARST	SR	D,FI,CC	11 / 1985
DYMOND TOWNSHIP	G	N	03 / 1983	DUNNVILLE	SL	D,FI	05 / 1981	LATCHFORD	SR	D,FI,AA	02 / 1983
ELORA	G	D	06 / 1981	ELLIOT LAKE	SL	D,FI,FL,AA	12 / 1985	LINDSAY	SR	D,FI	06 / 1981
ERIN	G	N	06 / 1981	ESSEX	SL	D,FI	07 / 1981	MARMORA	SR	D	07 / 1981
MATTAWA	G	N	02 / 1983	FENELON FALLS	SL	D,FI	06 / 1981	OTTAWA	SR	D,FI,FL,AA	01 / 1986
MILTON	G	N	07 / 1981	GODERICH	SL	D,FI,FL	12 / 1985	PEMBROKE	SR	D,FI,AA	01 / 1986
MOUNT FOREST	G	N	06 / 1981	GRAVENHURST	SL	D,AA	06 / 1981	PETERBOROUGH	SR	D,FI,FL	06 / 1981
NEW LISKEARD	G	D	03 / 1983	HAILEYBURY	SL	D,FI	03 / 1983	RAINY RIVER	SR	D,FI,AA	11 / 1986
NEWMARKET	G	D	12 / 1986	HAMILTON	SL	D,FI,FL	06 / 1981	STURGEON FALLS	SR	D,FI	02 / 1983
PLATTSVILLE	G	D	09 / 1986	HUNTSVILLE	SL	D,FI,AA	06 / 1981	SUDBURY	SR	D,FL,AA	12 / 1985
POWASSAN	G	N	03 / 1983	KENORA	SL	D,FI,FL,AA	11 / 1985	THORNE	SR	D	03 / 1983
SAULT ST. MARIE	G	D	11 / 1986	KINGSVILLE	SL	D,FI	07 / 1981	TIMMINS	SR	D,FI,CC	11 / 1985
SOUTH RIVER	G	D	02 / 1983	KIRKLAND LAKE	SL	D,FL	11 / 1985	TRENTON	SR	D,FI	07 / 1981
STRATHROY	G	D	10 / 1986	LEAMINGTON	SL	D,FI	07 / 1981	VERNER	SR	D,FI,AA	02 / 1983
TRENTON	G	D	07 / 1981	NANTICOKE	SL	D,FI	06 / 1981	WINDSOR	SR	D,FI,FL	12 / 1985

KEY TO TABLES

Ag	Silver
ALK	Alkalinity
Al	Aluminum
As	Arsenic
ASTM	ASTM-500
Ba	Barium
B	Boron
Ca	Calcium
Cd	Cadmium
C. Cl	Combined Chlorine
CN	Cyanide
Co	Cobalt
COND	Conductivity
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
F	Fluoride
F. Cl	Free Chlorine
Fe	Iron
HARD	Hardness
Hg	Mercury
KJELD	Nitrogen, Kjeldahl
LANG	Langeliers Index
Mg	Magnesium
MAX	Maximum
MEAN	Average
MIN	Minimum
Mo	Molybdenum
Mn	Manganese
Na	Sodium
NH3	Nitrogen, Ammonia
Ni	Nickel
NO2	Nitrate
NO3	Nitrite
n/u	no units
ODWO	Ontario Drinking Water Objective
P	Phosphorus
Pb	Lead
RES	Residue, Total
Sb	Antimony
Se	Selenium
SD	Standard Deviation
SiO3	Silica
SO4	Sulphate
TEMP (°C)	Temperature (degrees centigrade)
TURB	Turbidity
Zn	Zinc
# SAMP:	Number of samples analyzed
ALG.	Algae
BCKGRND COLIFORM	Background Coliform
CLAD	Cladocera
COPE	Copepoda
FECAL STREPT.	Fecal Streptococci
NEMA	Nematoda
OTHER MATERIALS	Other Materials
OTHER ORG.	Other Organisms
PROT.	Protozoa
STND. PLATE	Standard Plate Count

ONTARIO MUNICIPAL

WATER DISTRIBUTION SYSTEMS

1981, 1983, 1985, 1986

TABLE 1: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - (RAW) GROUND WATER SOURCES.

	pH	F. Cl	C. Cl	DO	TEMP (oC)
RANGES					
# SAMP	27	4	4	28	31
MIN	5.10	0.00	0.00	0.05	6.00
MAX	7.93	0.00	0.00	10.00	15.00
MEAN	7.07	0.00	0.00	3.77	10.20
SD	0.60	0.00	0.00	3.07	2.14
ODWO	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 2: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - (TREATED) GROUND WATER SOURCES.

	pH	F. Cl	C. Cl	DO	TEMP (oC)
RANGES					
# SAMP	15	13	13	15	14
MIN	5.10	0.00	0.00	1.40	6.00
MAX	7.94	1.30	3.20	10.40	16.00
MEAN	7.39	0.43	0.68	5.10	10.43
SD	0.70	0.48	1.02	3.33	2.63
ODWO	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 3: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - GROUND WATER SOURCES.

	pH (n/u)	F. Cl	C. Cl	DO	TEMP (oC) FLUSHED	TEMP (oC) RANDOM	TEMP (oC) OVERNIGHT
RANGES							
# SAMP	107	86	86	112	123	44	43
MIN	5.10	0.00	0.00	0.60	4.00	11.00	0.00
MAX	7.90	1.00	1.50	12.90	21.00	27.00	24.00
MEAN	7.12	0.11	0.14	4.38	12.23	18.31	18.55
SD	0.51	0.19	0.27	2.68	4.24	3.94	4.27
ODWO	-	-	-	-	-	-	-

TABLE 4: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - (RAW) SURFACE LAKE SOURCES.

	pH	F. Cl	C. Cl	DO	TEMP (oC) [illegible]
RANGES					
# SAMP	28	6	6	30	31
MIN	5.70	0.00	0.00	4.80	1.00
MAX	9.20	0.10	0.35	12.00	25.00
MEAN	7.40	0.02	0.08	9.39	10.84
SD	0.38	0.04	0.14	2.14	7.36
ODWO	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 5: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - (TREATED) SURFACE LAKE SOURCES.

	pH	F. Cl	C. Cl	DO	TEMP (oC)
RANGES					
# SAMP	31	31	33	32	34
MIN	4.70	0.10	0.05	3.20	1.50
MAX	9.30	2.00	2.00	14.00	26.00
MEAN	7.13	0.69	0.64	9.80	10.53
SD	0.89	0.55	0.55	2.75	7.47
ODWO	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 6: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - [illegible] SURFACE LAKE SOURCES.

	pH (n/u)	F. Cl	C. Cl	DO	TEMP (oC) FLUSHED	TEMP (oC) RANDOM	TEMP (oC) OVERNIGHT
RANGES							
# SAMP	193	190	211	200	214	39	38
MIN	0.00	0.00	0.00	1.80	1.50	10.50	0.00
MAX	9.20	1.80	2.00	14.00	24.00	26.00	23.00
MEAN	7.05	0.21	0.25	9.29	11.56	17.71	17.50
SD	0.92	0.33	0.28	2.62	5.69	3.39	3.97
ODWO	-	-	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 7: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - (RAW) SURFACE RIVER SOURCES.

	pH	F. Cl	C. Cl	DO	TEMP (oC)
	[illegible]				[illegible]
RANGES					
# SAMP	19	4	4	15	17
MIN	5.60	0.00	0.00	3.50	0.00
MAX	8.00	0.00	0.00	14.50	28.00
MEAN	7.28	0.00	0.00	10.34	11.58
SD	0.62	0.00	0.00	3.13	8.89
ODWO	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 8: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - (TREATED) SURFACE RIVER SOURCES.

	pH	F. Cl	C. Cl	DO	TEMP (oC)
	[illegible]				[illegible]
RANGES					
# SAMP	19	17	20	16	18
MIN	5.20	0.00	0.05	3.50	0.00
MAX	8.20	1.40	7.60	19.60	26.00
MEAN	7.13	0.59	0.88	10.74	11.25
SD	0.67	0.39	1.64	3.88	8.35
ODWO	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 9: DISTRIBUTION SYSTEMS STUDY - FIELD ANALYSIS (1981, 1983, 1985, 1986) - SURFACE RIVER SOURCES.

	pH (n/u)	F. Cl	C. Cl	DO	TEMP (oC) FLUSHED	TEMP (oC) RANDOM	TEMP (oC) OVERNIGHT
RANGES							
# SAMP	117	102	123	112	127	8	9
MIN	4.60	0.00	0.00	0.00	0.00	0.00	0.00
MAX	8.00	1.10	1.50	16.00	27.00	23.00	18.00
MEAN	7.00	0.20	0.35	9.33	11.96	13.75	10.78
SD	0.60	0.28	0.31	2.77	6.96	6.92	6.72
ODWO	-	-	-	-	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 10: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (RAW) GROUND WATER SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
RANGES																					
# SAMP	32	32	32	31	31	32	30	32	32	27	27	25	28	28	28	22	28	28	28	28	13
MIN	17.50	10.20	6.79	-0.20	0.20	53.00	46.00	3.70	1.50	9.02	-3.35	0.01	0.10	0.00	0.01	0.01	0.10	0.00	0.05	0.02	2.22
MAX	1470.00	386.00	8.30	47.00	44.00	2090.00	2100.00	496.00	75.70	12.99	0.81	1.00	8.91	0.06	7.30	1.00	6.83	11.30	990.00	2.06	100.00
MEAN	306.35	206.28	7.72	7.06	3.65	587.00	493.02	82.20	24.70	12.05	-0.13	0.15	0.61	0.01	1.28	0.18	1.59	5.94	98.21	0.34	25.92
SD	285.72	79.60	0.42	10.39	8.48	381.90	449.15	93.46	15.40	0.37	0.92	0.19	1.64	0.01	1.39	0.27	1.57	2.94	237.69	0.45	32.22
ODWO	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

LL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 11: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (TREATED) GROUND WATER SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH u	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
RANGES																					
# SAMP	15	15	15	14	14	15	13	15	15	14	14	14	15	15	15	14	15	15	15	13	9
MIN	22.40	8.60	6.26	0.00	0.20	103.40	72.30	6.50	1.50	8.41	-3.96	0.01	0.07	0.00	0.01	0.01	0.20	0.20	0.05	0.02	6.00
MAX	1350.00	327.00	8.20	32.00	3.60	2000.00	1940.00	452.00	75.60	12.34	1.32	1.00	6.90	0.06	5.69	0.30	7.70	13.30	980.00	1.46	113.00
MEAN	392.54	206.23	7.61	6.98	1.10	710.29	658.98	107.46	30.22	12.04	0.10	0.14	0.56	0.02	0.97	0.20	2.10	7.43	172.95	0.43	32.46
SD	372.34	71.43	0.47	10.11	1.01	496.38	576.10	121.19	21.56	1.27	1.24	0.25	1.73	0.02	1.63	0.24	2.07	3.55	312.19	0.44	39.29
ODWO	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

LE 12: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (FLUSHED) GROUND WATER SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
ES																					
SAMP	118	117	118	114	117	115	111	118	118	104	104	98	104	107	107	88	107	107	107	99	53
	0.10	9.60	6.19	-1.10	0.04	86.60	55.00	0.01	0.01	2.10	-3.97	0.00	0.06	0.00	0.01	0.01	0.10	0.00	0.20	0.02	6.00
	1360.00	469.10	8.30	158.30	56.00	2420.00	1960.00	464.00	81.10	13.08	1.30	1.00	3.87	0.08	8.83	0.50	5.22	13.20	950.00	1.72	603.00
EAN	310.17	188.14	7.59	7.22	2.50	616.48	525.52	86.00	23.36	11.76	-0.29	0.11	0.26	0.01	1.55	0.17	1.30	6.48	117.79	0.35	47.32
	321.78	80.05	0.48	17.90	7.07	431.30	474.72	100.82	18.96	1.50	1.28	0.12	0.39	0.01	1.31	0.22	0.38	2.67	242.73	0.42	94.99
	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

ABLE 13: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (RAW) SURFACE LAKE SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
ANGES																					
MP	28	28	28	25	25	28	28	28	28	25	28	28	28	28	28	27	28	28	28	23	13
IN	13.40	6.00	6.58	1.00	0.36	41.00	29.00	3.00	1.00	8.50	-3.87	0.00	0.02	0.00	0.04	0.01	1.00	0.05	1.80	0.02	1.04
AX	159.00	265.10	8.23	55.90	16.00	330.00	605.00	47.10	11.50	12.24	0.46	0.65	0.75	0.05	3.43	0.50	16.00	3.75	32.00	0.16	27.70
E	74.21	63.62	7.59	15.27	2.75	165.01	141.68	22.50	4.44	10.81	-0.95	0.13	0.36	0.01	0.39	0.08	4.32	1.37	13.33	0.07	6.06
D	48.45	58.39	0.46	12.34	3.55	91.85	112.00	15.15	3.04	1.23	1.22	0.13	0.17	0.01	0.67	0.11	3.36	0.93	7.03	0.04	7.09
DWO	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

LL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 14: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (TREATED) SURFACE LAKE SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
RANGES																					
# SAMP	34	34	34	31	31	34	34	34	34	31	34	34	33	33	33	32	34	34	34	28	14
MIN	12.00	1.80	4.64	0.00	0.24	35.00	12.00	2.80	1.00	5.90	-6.47	0.00	0.02	0.00	0.05	0.01	1.00	0.05	1.50	0.02	0.67
MAX	151.30	188.90	9.70	27.00	2.20	320.00	550.00	45.40	10.60	12.33	0.48	0.32	0.60	0.02	3.67	0.50	15.00	3.75	34.00	1.05	16.25
MEAN	70.34	54.72	7.56	6.58	0.72	171.19	133.76	21.32	4.14	10.75	-1.14	0.10	0.26	0.01	0.42	0.06	3.86	1.34	18.92	0.38	6.92
SD	44.45	41.15	0.79	6.57	0.55	76.79	92.81	13.79	2.72	1.33	1.47	0.07	0.13	0.01	0.65	0.11	2.76	0.83	10.04	0.43	4.81
ODWO	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 15: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (FLUSHED) SURFACE LAKE SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
RANGES																					
# SAMP	210	210	210	189	189	210	210	210	210	181	202	202	199	199	199	193	202	201	202	182	106
MIN	10.00	2.20	4.77	0.00	0.14	36.00	30.00	3.00	1.00	6.22	-6.15	0.00	0.02	0.00	0.05	0.01	0.40	0.05	1.00	0.01	0.94
MAX	158.80	199.30	9.70	61.90	25.00	343.00	645.00	47.40	11.00	12.26	1.43	0.41	1.40	0.02	4.15	0.50	16.00	8.90	99.00	1.33	57.20
MEAN	73.39	57.19	7.51	6.95	0.78	179.67	145.28	22.58	4.21	10.74	-1.10	0.11	0.27	0.01	0.48	0.07	3.69	1.61	19.50	0.44	7.41
SD	43.48	41.63	0.66	8.12	1.36	76.74	92.83	13.69	2.64	1.17	1.36	0.08	0.15	0.01	0.75	0.12	2.99	1.29	11.08	0.43	7.49
ODWO	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

LE 16: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (RAW) SURFACE RIVER SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
GES																					
SAMP	21	21	21	18	18	21	21	21	21	15	18	20	20	20	20	16	20	20	20	19	9
	20.50	14.60	6.53	0.63	0.54	62.50	27.20	4.30	1.00	9.84	-2.90	0.30	0.20	0.00	0.10	0.01	1.00	0.55	1.94	0.03	0.79
	260.00	185.00	8.28	109.00	19.00	610.00	1040.00	79.00	21.00	12.76	1.47	0.51	1.20	0.09	7.90	0.10	26.00	13.80	93.00	0.77	11.40
.N	91.51	67.23	7.69	29.64	3.08	200.08	195.11	27.64	5.39	11.13	-0.85	0.16	0.57	0.02	0.79	0.04	7.76	2.71	18.93	0.09	4.72
	70.38	49.01	0.38	25.25	4.53	151.35	227.91	21.32	5.12	1.04	1.13	0.14	0.27	0.02	1.72	0.03	5.65	2.32	21.83	0.17	3.90
O	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

LE 17: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (TREATED) SURFACE RIVER SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
IGES																					
MP	23	23	23	20	20	23	23	23	23	17	20	21	20	21	21	17	21	21	21	20	9
	22.40	2.40	5.59	0.70	0.18	61.00	40.00	6.00	1.80	7.24	-5.13	0.02	0.06	0.00	0.10	0.01	1.00	0.55	11.50	0.02	1.16
(	308.00	184.00	8.23	63.30	2.60	680.00	575.00	82.00	25.00	12.76	1.28	0.40	1.00	0.33	8.15	0.11	16.20	4.70	98.00	0.91	32.50
	109.24	69.36	7.58	11.95	0.95	259.17	175.10	33.42	6.23	11.02	-0.94	0.15	0.39	0.03	0.82	0.02	5.25	2.04	31.80	0.25	3.09
	83.97	57.47	0.55	15.85	0.70	172.51	132.35	24.57	6.47	1.42	1.52	0.11	0.25	0.07	1.75	0.03	4.02	1.05	22.08	0.34	9.36
_	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

. RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 18: DISTRIBUTION SYSTEMS STUDY - GENERAL CHEMISTRY (1981, 1983, 1985, 1986) - (FLUSHED) SURFACE RIVER SOURCES.

	HARD (CaCO3)	ALK (CaCO3)	pH	COLOUR (TCU)	TURB (FTU)	COND (umho/cm)	RES	Ca	Mg	ASTM (n/u)	LANG (n/u)	NH3	KJELD	NO2	NO3	P	DOC	SiO3	SO4	F	Na
RANGES																					
# SAMP	118	118	118	97	97	118	118	118	118	90	111	110	109	110	110	90	110	110	109	104	53
MIN	1.00	2.40	5.31	0.60	0.18	57.20	18.20	1.00	1.00	7.03	-5.34	0.02	0.04	0.00	0.10	0.01	0.70	0.65	11.00	0.01	1.15
MAX	324.00	218.00	8.40	67.30	3.40	720.00	575.00	93.00	24.00	12.96	1.35	0.44	1.00	0.35	7.81	0.45	9.50	7.30	100.00	0.39	59.40
MEAN	119.35	76.75	7.61	9.71	0.79	287.72	192.69	36.05	7.05	11.16	-0.84	0.14	0.40	0.02	1.05	0.03	3.89	2.26	35.40	0.25	7.74
SD	88.69	57.53	0.55	12.50	0.64	191.99	140.01	25.46	6.66.	1.37	1.46	0.10	0.24	0.04	1.83	0.05	2.42	1.20	26.07	0.32	9.33
ODWO	-	-	-	5	1	-	-	-	-	-	-	-	-	1	10	-	-	-	500	2.4	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 19: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (RAW) GROUND WATER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	
RANGES																			
# SAMP	32	31	12	21	31	19	26	31	22	31	31	21	31	11	10	31	21	21	
MIN	0.000	0.004	0.001	0.001	0.005	0.010	0.000	0.001	0.001	0.001	0.005	0.002	0.000	0.000	0.001	0.001	0.001	0.000	0.
MAX	15.000	1.300	0.002	0.014	0.360	0.570	0.002	0.050	0.050	0.044	4.350	0.010	0.142	0.000	0.012	0.050	0.003	0.320	0.
MEAN	9.631	0.133	0.001	0.002	0.080	0.100	0.001	0.008	0.013	0.011	0.557	0.004	0.025	0.000	0.007	0.011	0.001	0.006	0.
SD	3.265	0.254	0.000	0.004	0.070	0.125	0.001	0.011	0.020	0.010	1.054	0.002	0.034	0.000	0.005	0.018	0.000	0.005	0.
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 20: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (TREATED) GROUND WATER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	16	15	9	12	15	10	10	15	12	15	15	10	15	5	3	15	12	12	15
MIN	0.000	0.003	0.001	0.001	0.005	0.014	0.000	0.001	0.001	0.001	0.008	0.002	0.002	0.000	0.001	0.001	0.001	0.002	0.001
MAX	16.000	0.310	0.002	0.002	0.274	0.540	0.001	0.040	0.050	0.080	0.840	0.060	0.100	0.000	0.014	0.050	0.005	0.020	0.056
MEAN	9.125	0.061	0.001	0.001	0.076	0.133	0.000	0.013	0.022	0.018	0.328	0.010	0.025	0.000	0.006	0.019	0.002	0.007	0.014
SD	4.322	0.081	0.000	0.000	0.068	0.155	0.000	0.013	0.025	0.020	0.292	0.018	0.026	0.000	0.007	0.023	0.001	0.006	0.017
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 21: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (FLUSHED) GROUND WATER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	125	117	53	37	112	35	92	118	34	117	117	77	117	48	31	118	37	37	117
MIN	0.000	0.003	0.001	0.001	0.001	0.004	0.000	0.001	0.001	0.001	0.006	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.001
MAX	21.000	0.280	0.002	0.002	0.160	0.430	0.003	0.050	0.070	0.790	8.150	0.032	0.142	0.000	0.050	0.050	0.005	0.020	0.120
MEAN	12.039	0.069	0.001	0.001	0.057	0.085	0.000	0.008	0.018	0.076	0.440	0.004	0.023	0.000	0.008	0.014	0.001	0.007	0.014
SD	4.484	0.079	0.000	0.000	0.038	0.088	0.001	0.011	0.023	0.117	0.796	0.005	0.029	0.000	0.011	0.020	0.001	0.006	0.017
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 22: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (RANDOM) GROUND WATER SOURCES.

RANGES

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
# SAMP	57	76	54	70	71	68	50	76	60	76	76	44	76	4	6	76	70	70	76
MIN	0.000	0.003	0.001	0.001	0.001	0.005	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.001	0.001	0.001	0.000	0.001
MAX	27.000	0.290	0.002	0.003	0.150	0.400	0.005	0.050	0.070	2.330	3.200	0.820	0.091	0.000	0.023	0.620	0.004	0.020	1.700
MEAN	15.856	0.046	0.001	0.001	0.053	0.078	0.001	0.011	0.023	0.392	0.305	0.043	0.021	0.000	0.007	0.039	0.001	0.007	0.155
SD	6.762	0.062	0.000	0.000	0.037	0.076	0.001	0.013	0.024	0.498	0.486	0.140	0.021	0.000	0.009	0.083	0.001	0.007	0.363
CDWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 23: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (OVERNIGHT) GROUND WATER SOURCES.

RANGES

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Ni	Se	Ag	Zn
# SAMP	45	53	53	53	48	51	27	53	53	53	53	23	53	53	53	53	51
MIN	0.000	0.003	0.001	0.001	0.001	0.005	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.000	0.002
MAX	24.000	0.160	0.002	0.003	0.150	0.200	0.003	0.050	0.080	2.590	3.060	0.076	0.080	0.060	0.006	0.020	3.540
MEAN	18.056	0.038	0.001	0.001	0.053	0.065	0.001	0.015	0.026	0.425	0.258	0.011	0.020	0.025	0.001	0.008	0.242
SD	5.006	0.042	0.000	0.000	0.040	0.054	0.001	0.013	0.025	0.518	0.444	0.018	0.017	0.022	0.001	0.008	0.725
CDWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 24: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (RAW) SURFACE LAKE SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	35	33	15	20	33	33	31	33	28	33	33	31	33	18	13	33	20	20	33
MIN	0.000	0.005	0.001	0.001	0.005	0.005	0.000	0.001	0.001	0.001	0.012	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001
MAX	25.000	1.530	0.002	0.002	0.050	0.060	0.001	0.017	0.050	0.065	1.070	0.036	0.044	0.000	0.021	0.110	0.002	0.020	0.032
MEAN	9.289	0.155	0.001	0.001	0.029	0.019	0.000	0.005	0.005	0.017	0.202	0.004	0.015	0.000	0.008	0.013	0.002	0.012	0.010
SD	7.514	0.237	0.000	0.000	0.016	0.014	0.000	0.004	0.013	0.015	0.263	0.006	0.011	0.000	0.008	0.024	0.001	0.028	0.007
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 25: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (TREATED) SURFACE LAKE SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	38	36	16	24	36	24	34	36	28	36	36	34	36	21	12	36	24	24	36
MIN	0.000	0.000	0.001	0.001	0.005	0.005	0.000	0.001	0.001	0.001	0.005	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001
MAX	26.000	2.000	0.002	0.002	0.050	0.120	0.005	0.032	0.050	0.100	0.220	0.009	0.026	0.000	0.012	0.080	0.002	0.020	0.280
MEAN	9.576	0.182	0.001	0.001	0.027	0.022	0.000	0.005	0.005	0.021	0.051	0.003	0.009	0.000	0.003	0.011	0.001	0.011	0.018
SD	7.515	0.233	0.000	0.000	0.017	0.024	0.001	0.006	0.013	0.024	0.049	0.002	0.005	0.000	0.003	0.018	0.001	0.008	0.046
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 26: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (FLUSHED) SURFACE LAKE SOURCES.

	TEMP(oC)	Al	Sb	As	Be	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	222	215	113	156	217	155	203	217	174	217	217	197	217	132	62	217	156	155	217
MIN	0.000	0.003	0.001	0.001	0.001	0.005	0.000	0.000	0.001	0.001	0.005	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.000
MAX	24.000	2.400	0.002	0.002	0.074	0.140	0.002	0.022	0.050	0.899	2.300	0.038	0.122	0.000	0.014	0.060	0.006	0.020	0.270
MEAN	11.244	0.141	0.001	0.001	0.029	0.019	0.000	0.005	0.006	0.059	0.086	0.004	0.009	0.000	0.003	0.009	0.002	0.011	0.018
SD	5.322	0.308	0.000	0.000	0.018	0.016	0.000	0.004	0.013	0.092	0.177	0.004	0.010	0.000	0.004	0.014	0.001	0.008	0.035
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 27: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (RANDOM) SURFACE LAKE SOURCES.

	TEMP(oC)	Al	Sb	As	Be	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	113	151	112	136	151	136	137	150	126	151	151	136	151	27	15	151	136	136	151
MIN	0.000	0.001	0.001	0.001	0.003	0.005	0.000	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001
MAX	26.000	1.700	0.002	0.002	0.066	0.340	0.110	0.035	0.050	4.700	3.300	0.210	0.240	0.000	0.130	0.060	0.005	0.020	1.300
MEAN	15.112	0.113	0.001	0.001	0.035	0.019	0.001	0.006	0.007	0.485	0.148	0.016	0.011	0.000	0.012	0.014	0.002	0.012	0.112
SD	5.614	0.217	0.000	0.000	0.017	0.030	0.009	0.005	0.015	0.531	0.398	0.030	0.020	0.000	0.033	0.015	0.001	0.009	0.264
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 28: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (OVERNIGHT) SURFACE LAKE SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
RANGES																		
# SAMP	99	111	111	111	111	112	97	111	111	111	111	97	111	22	111	111	111	111
MIN	0.000	0.005	0.001	0.001	0.010	0.005	0.000	0.001	0.001	0.001	0.007	0.001	0.001	0.000	0.001	0.001	0.000	0.001
MAX	24.000	0.350	0.002	0.002	0.050	0.030	0.002	0.025	0.050	4.910	3.840	0.118	0.031	0.000	0.080	0.009	0.020	3.240
MEAN	16.652	0.080	0.001	0.001	0.041	0.012	0.000	0.007	0.008	0.546	0.123	0.013	0.010	0.000	0.018	0.002	0.013	0.179
SD	4.221	0.070	0.000	0.000	0.013	0.004	0.000	0.004	0.016	0.376	0.374	0.019	0.005	0.000	0.017	0.001	0.009	0.417
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 29: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (RAW) SURFACE RIVER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	19	21	9	12	21	12	21	21	18	21	21	21	21	11	9	21	12	12	21
MIN	0.000	0.030	0.001	0.001	0.007	0.005	0.000	0.001	0.001	0.001	0.020	0.001	0.005	0.000	0.001	0.001	0.001	0.000	0.001
MAX	28.000	0.702	0.002	0.002	0.160	0.070	0.000	0.010	0.002	0.273	1.190	0.012	0.056	0.001	0.003	0.050	0.002	0.020	0.039
MEAN	10.358	0.198	0.001	0.001	0.034	0.020	0.000	0.004	0.001	0.034	0.268	0.003	0.021	0.000	0.002	0.007	0.001	0.010	0.008
SD	9.140	0.163	0.000	0.000	0.032	0.018	0.000	0.003	0.000	0.061	0.272	0.003	0.013	0.000	0.001	0.011	0.001	0.009	0.008
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 30: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (TREATED) SURFACE RIVER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	20	23	9	13	22	13	23	23	19	23	23	22	23	11	9	22	13	13	23
MIN	0.000	0.028	0.001	0.001	0.005	0.005	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
MAX	26.000	0.710	0.002	0.002	0.050	0.080	0.002	0.020	0.020	0.240	0.630	0.012	0.536	0.000	0.002	0.040	0.002	0.020	0.064
MEAN	10.125	0.166	0.001	0.001	0.027	0.024	0.000	0.004	0.002	0.032	0.092	0.003	0.035	0.000	0.001	0.008	0.001	0.009	0.014
SD	8.627	0.151	0.000	0.000	0.015	0.020	0.000	0.005	0.004	0.051	0.132	0.002	0.109	0.000	0.001	0.011	0.001	0.009	0.016
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 31: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (FLUSHED) SURFACE RIVER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	128	118	53	71	114	71	118	118	100	118	118	114	118	66	43	115	70	71	115
MIN	0.000	0.002	0.001	0.001	0.001	0.005	0.000	0.000	0.001	0.002	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.001
MAX	27.000	1.200	0.002	0.002	0.059	0.090	0.004	0.022	0.020	0.300	0.410	0.022	0.030	0.001	0.004	0.040	0.009	0.030	0.079
MEAN	11.370	0.136	0.001	0.001	0.029	0.021	0.000	0.005	0.002	0.042	0.070	0.004	0.010	0.000	0.002	0.006	0.002	0.009	0.012
SD	7.008	0.165	0.000	0.000	0.016	0.020	0.001	0.005	0.004	0.050	0.079	0.004	0.006	0.000	0.001	0.007	0.001	0.009	0.012
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 32: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (RANDOM) SURFACE RIVER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	Zn
RANGES																			
# SAMP	55	77	53	63	76	63	76	76	56	77	77	77	77	28	13	77	62	63	77
MIN	0.000	0.005	0.001	0.001	0.001	0.005	0.000	0.000	0.001	0.007	0.010	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.001
MAX	25.000	0.600	0.002	0.002	0.060	0.090	0.002	0.021	0.020	4.200	3.000	0.100	0.062	0.000	0.006	0.380	0.002	0.020	0.330
MEAN	14.745	0.117	0.001	0.001	0.029	0.019	0.000	0.005	0.002	0.276	0.097	0.013	0.011	0.000	0.002	0.014	0.001	0.010	0.094
SD	5.141	0.104	0.000	0.000	0.019	0.018	0.000	0.004	0.002	0.565	0.340	0.020	0.008	0.000	0.001	0.045	0.001	0.009	0.160
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 33: DISTRIBUTION SYSTEMS STUDY - METALS (1981, 1983, 1985, 1986) - (OVERNIGHT) SURFACE RIVER SOURCES.

	TEMP(oC)	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
RANGES																		
# SAMP	47	49	49	49	49	49	49	49	49	49	49	49	49	28	49	49	49	49
MIN	4.000	0.001	0.001	0.001	0.005	0.005	0.000	0.000	0.001	0.009	0.005	0.001	0.001	0.000	0.002	0.001	0.000	0.001
MAX	31.000	0.497	0.002	0.002	0.050	0.030	0.036	0.030	0.002	0.396	3.510	0.063	0.070	0.000	0.090	0.002	0.020	1.170
MEAN	17.257	0.116	0.001	0.001	0.032	0.013	0.001	0.007	0.002	0.222	0.132	0.010	0.011	0.000	0.013	0.002	0.011	0.096
SD	4.324	0.103	0.000	0.000	0.021	0.009	0.005	0.005	0.000	0.223	0.511	0.014	0.009	0.000	0.017	0.000	0.010	0.128
ODWO	-	-	-	0.5	1.0	5.0	0.005	0.05	-	1.0	0.3	0.05	0.05	0.001	-	0.01	0.5	5.0

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED.

TABLE 34: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (RAW) GROUND WATER SOURCES.

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCKGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHER MAT./L
RANGES												
# SAMP	19	28	28	17	20	20	20	20	20	20	17	17
MIN	0	0	0	0	0	0	0	0	0	0	0	0
MAX	3.00	270.00	1600.00	22.00	400.00	2.14	0.20	0.00	0.47	7.10	96.00	7.10
MEAN	1.32	10.50	79.39	3.53	61.35	0.17	0.01	0.00	0.06	0.38	5.94	0.68
SD	1.00	50.87	303.63	5.06	140.38	0.47	0.04	0.00	0.14	1.58	23.24	1.98
ODWO	UD	5	-	UD	500	-	-	-	-	-	-	-

ALL RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

TABLE 35: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (TREATED) GROUND WATER SOUR

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCKGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHER MAT./L
RANGES												
# SAMP	8	15	15	8	12	12	12	12	12	12	9	9
MIN	0	0	0	0	0	0	0	0	0	0	0	0
MAX	2.00	2.00	240.00	4.00	10000.00	0.67	0.00	0.00	0.67	11.20	63.40	2.60
MEAN	0.50	0.53	24.67	0.75	988.83	0.11	0.00	0.00	0.09	1.03	7.47	0.38
SD	0.76	0.83	65.86	1.39	2862.04	0.20	0.00	0.00	0.19	3.22	21.01	0.57
ODWO	UD	5	-	UD	500	-	-	-	-	-	-	-

ALL RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

TABLE 36: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (FLUSHED) GROUND WATER SOURC

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCXGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHER MAT./L
RANGES												
# SAMP	43	111	111	42	80	106	106	106	106	106	87	87
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAX	2.00	11.00	2400.00	2.00	12000.00	123.00	61.00	0.04	68.00	10.00	69.00	18.00
MEAN	0.44	0.59	113.49	0.43	592.13	2.51	0.58	0.00	0.76	0.24	2.44	0.37
SD	0.63	1.44	359.86	0.59	2218.20	12.71	5.92	0.00	6.62	1.21	9.51	2.07
ODWO	UD	5	-	UD	500	-	-	-	-	-	-	-

ALL RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

LE 37: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (RAW) SURFACE LAKE SOURCES.

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCXGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHE MAT.
GES												
AMP	29	31	31	29	14	19	19	19	19	19	19	
	1.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	90.000	900.000	52000.000	25.000	10000.000	9.380	10.530	10.420	18.000	74.000	17283.000	4994
	8.069	58.935	5373.323	4.483	1319.000	1.164	1.516	1.028	3.042	6.549	2352.068	432
	17.529	161.623	12631.338	5.396	2808.864	2.417	2.929	2.595	5.568	17.405	4645.584	1256
	UD	5	-	UD	500	-	-	-	-	-	-	-

RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

TABLE 38: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (TREATED) SURFACE LAKE SOURC

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCXGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OT MA
RANGES												
# SAMP	17	33	33	17	25	30	30	30	30	30	30	
MIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
MAX	2.000	4.000	850.000	4.000	10000.000	5.240	13.100	13.890	69.000	2.000	1198.000	78
MEAN	1.059	0.758	52.848	1.294	403.505	0.259	0.614	0.908	4.289	0.189	113.733	4
SD	0.556	1.062	171.778	1.105	1999.275	0.967	2.405	3.178	13.778	0.438	291.734	16
ODWO	UD	5	-	UD	500	-	-	-	-	-	-	

ALL RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

ABLE 39: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (FLUSHED) SURFACE LAKE SOURCES

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCXGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTH MAT.
ANGES												
SAMP	99	204	204	99	168	211	211	211	211	211	211	
IN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
AX	5.000	17.000	16700.000	2.000	1300.000	13.910	36.000	32.200	90.130	10.000	50600.000	81
EAN	0.919	0.794	222.127	0.879	29.853	0.452	0.350	0.222	2.473	0.188	988.147	1
D	0.566	1.735	1547.942	0.358	124.734	1.552	2.610	2.236	9.952	0.947	5232.522	9
DWO	UD	5	-	UD	500	-	-	-	-	-	-	-

LL RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

BLE 40: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (RAW) SURFACE RIVER SOURCES.

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCKGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHER MAT./L
NGES												
SAMP	20	23	21	20	11	7	7	7	6	6	7	6
N	1.000	0.000	8.000	4.000	30.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	570.000	12000.000	400000.000	400.000	6300.000	21.350	3.800	8.100	6.790	33.500	1850.000	118.000
EAN	63.950	1103.174	44915.905	41.850	1775.318	3.167	0.614	1.174	1.132	11.850	632.429	38.383
	150.807	2852.446	99548.254	86.751	1835.249	8.022	1.410	3.054	2.772	12.683	841.600	49.602
O	UD	5	-	UD	500	-	-	-	-	-	-	-

L RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

LE 41: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (TREATED) SURFACE RIVER SOURCE

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCKGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHER MAT./L
NGES												
AMP	8	23	23	8	16	17	17	17	17	17	18	17
N	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1.000	3.000	134.000	1.000	2400.000	23.620	0.100	0.250	1.560	0.200	19768.000	6.200
AN	1.000	0.609	9.652	1.000	155.599	1.662	0.009	0.015	0.265	0.024	1099.011	0.400
	0.000	1.033	29.004	0.000	598.551	5.714	0.026	0.061	0.496	0.057	4659.166	1.498
O	UD	5	-	UD	500	-	-	-	-	-	-	-

L RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

TABLE 42: DISTRIBUTION SYSTEMS STUDY - BACTERIOLOGY AND BIOLOGICAL CONTENT (1981, 1983, 1985, 1986) - (FLUSHED) SURFACE RIVER SOURC

	FECAL COLIFORM /100mL	TOTAL COLIFORM /100mL	BCKGRND COLIFORM /100mL	FECAL STREPT. /100mL	STND. PLATE /mL	NEMA/L	COPE/L	CLAD/L	OTHER ORG./L	PROT./L	ALG./L	OTHER MAT./L
RANGES												
# SAMP	55	126	126	49	96	119	119	119	116	116	119	117
MIN	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MAX	1.000	6.000	44000.000	5.000	2400.000	16.320	4.550	6.070	4.500	0.800	39882.000	140.000
MEAN	0.891	0.897	569.595	1.082	230.393	1.062	0.134	0.120	0.231	0.033	995.360	2.472
SD	0.315	1.264	3999.648	0.571	621.664	2.982	0.648	0.650	0.626	0.127	5377.690	14.160
ODWO	UD	5	-	UD	500	-	-	-	-	-	-	-

ALL RESULTS REFER TO THE NUMBER OF ORGANISMS PRESENT; UD INDICATES UNDETECTABLE.

TABLE 43: DISTRIBUTION SYSTEMS STUDY - (1981, 1983, 1985, 1986) - FLUSHED SAMPLES ONLY (ALL RESIDENCES).

	FLUSHED Cd	FLUSHED Cu	FLUSHED Pb	FLUSHED Zn	RANDOM Cd	RANDOM Cu	RANDOM Pb	RANDOM Zn	OVERNIGHT Cd	OVERNIGHT Cu	OVERNIGHT Pb	OVERNIGHT Zn	pH (n/u) FIELD	ALK (CaCO3) GCHEM
RANGES														
# SAMP	423	462	400	462	261	301	258	301	180	220	176	218	411	469
MIN	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.001	4.600	2.200
MAX	0.004	0.899	0.038	0.270	0.110	4.700	0.820	1.300	0.036	4.910	0.152	3.540	9.200	469.100
MEAN	0.000	0.059	0.004	0.015	0.001	0.409	0.020	0.118	0.001	0.435	0.012	0.170	7.078	94.969
SD	0.000	0.090	0.004	0.026	0.007	0.704	0.063	0.273	0.003	0.692	0.020	0.469	0.676	79.164
ODWO	0.005	1.0	0.05	5.0	0.005	1.0	0.05	5.0	0.005	1.0	0.05	5.0	-	-

LL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 44: DISTRIBUTION SYSTEMS STUDY - (1981, 1983, 1985, 1986) - FLUSHED SAMPLES ONLY (RESIDENCES WITH COPPER PLUMBING).

	FLUSHED Cd	FLUSHED Cu	FLUSHED Pb	FLUSHED Zn	RANDOM Cd	RANDOM Cu	RANDOM Pb	RANDOM Zn	OVERNIGHT Cd	OVERNIGHT Cu	OVERNIGHT Pb	OVERNIGHT Zn	pH FIELD	ALK (CaCO3) GCHEM	LANG (n/u)
RANGES															
# SAMP	229	264	225	264	180	215	177	215	136	172	132	170	240	264	253
MIN	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.002	4.600	2.200	-6.150
MAX	0.003	0.899	0.032	0.160	0.003	4.700	0.820	1.700	0.003	4.910	0.152	3.540	9.100	469.100	1.430
MEAN	0.000	0.074	0.003	0.015	0.000	0.498	0.023	0.118	0.000	0.495	0.009	0.175	6.925	82.712	-1.124
SD	0.000	0.109	0.003	0.024	0.000	0.769	0.075	0.264	0.000	0.756	0.017	0.515	0.701	80.527	1.586
ODWO	0.005	1.0	0.05	5.0	0.005	1.0	0.05	5.0	0.005	1.0	0.05	5.0	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.

TABLE 45: DISTRIBUTION SYSTEMS STUDY - (1981, 1983, 1985, 1986) - FLUSHED SAMPLES ONLY (RESIDENCES WITH LEAD SERVICE CONNECTIONS).

	FLUSHED Cd	FLUSHED Cu	FLUSHED Pb	FLUSHED Zn	RANDOM Cd	RANDOM Cu	RANDOM Pb	RANDOM Zn	OVERNIGHT Cd	OVERNIGHT Cu	OVERNIGHT Pb	OVERNIGHT Zn	pH FIELD	ALK (CaCO3) GCHEM	LANG (n/u)
RANGES															
# SAMP	39	39	38	39	39	39	38	39	27	27	27	27	35	39	37
MIN	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	6.100	16.000	-1.740
MAX	0.001	0.420	0.038	0.270	0.110	3.400	0.102	1.800	0.036	1.140	0.118	1.170	8.300	200.000	1.350
MEAN	0.000	0.038	0.009	0.019	0.003	0.308	0.021	0.143	0.002	0.269	0.027	0.165	7.244	70.586	-0.163
SD	0.000	0.069	0.009	0.044	0.018	0.616	0.026	0.408	0.007	0.362	0.031	0.315	0.460	47.745	0.819
ODWO	0.005	1.0	0.05	5.0	0.005	1.0	0.05	5.0	0.005	1.0	0.05	5.0	-	-	-

ALL RESULTS ARE IN mg/L UNLESS OTHERWISE STATED; (n/u) INDICATES NO UNITS.